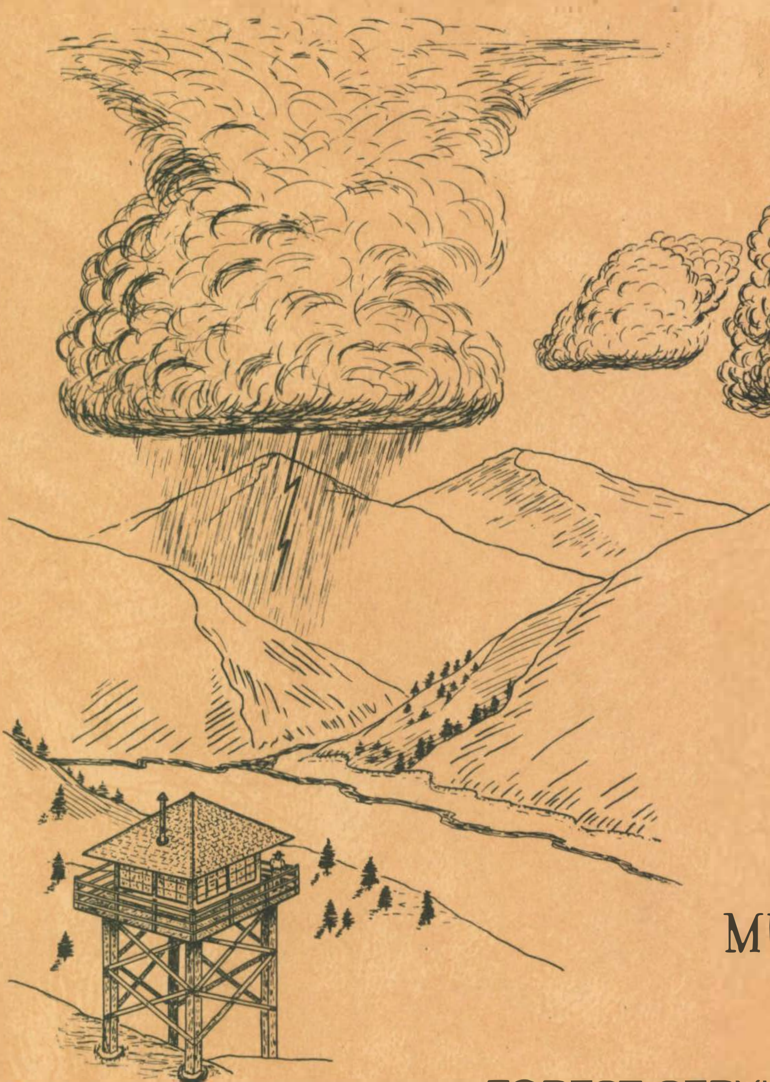
by Robert to Pete Martinelli

PAUL B. MacCREADY Jr., VINCENT J. SCHAEFER, JOHN H. DIETERICH, J. S. BARROWS



INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION

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PROJECT SKYFIRE

CLOUD AND LIGHTNING OBSERVATION HANDBOOK

by

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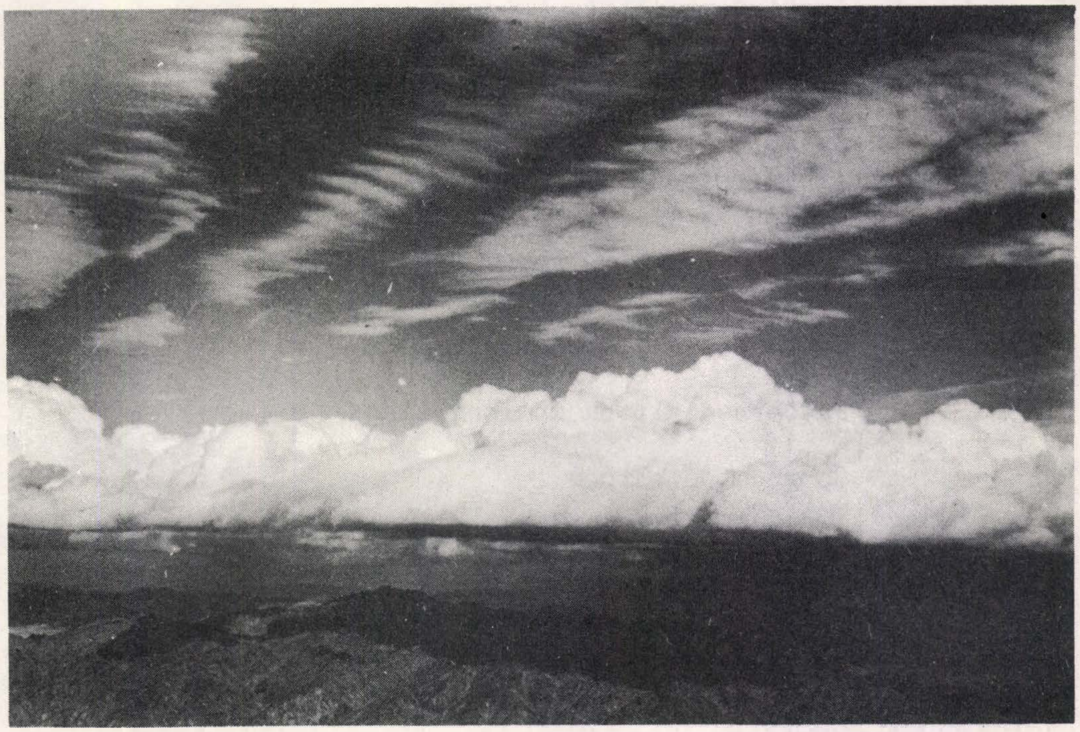


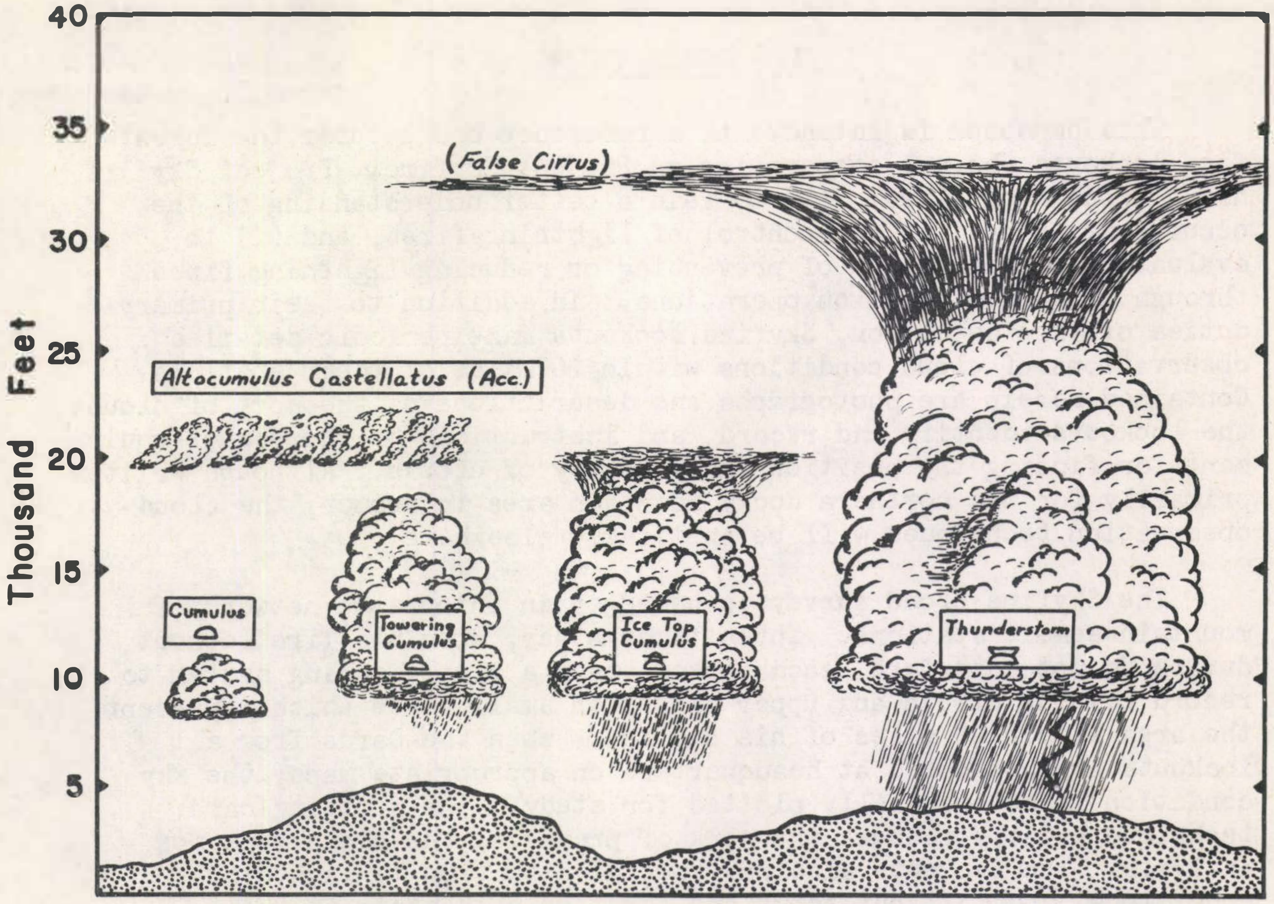
Figure 1. Cumulus clouds and upper clouds. Long segmented bands of high cirrus clouds show the presence of a fast-moving stream of air--the jet stream; underneath, towering cumulus clouds mark an area of upcurrents where rain and lightning can begin. Over a large area cloud observers collect data on such cloud forms. The information is used in investigating actual lightning occurrences and fire danger in order to learn more about why lightning exists, how it may be controlled, and how fire danger is related to meteorological variables.

I. INTRODUCTION

This handbook is intended as a reference booklet for the forest-fire lookouts who are cooperating on Project Skyfire. Project Skyfire has 2 broad objectives: (1) to gain a better understanding of the occurrence, behavior, and control of lightning fires, and (2) to evaluate the possibility of preventing or reducing lightning fires through cloud-modification operations. In addition to their primary duties of fire detection, Skyfire lookouts make periodic detailed observations of cloud conditions within 20 miles of their stations. Contained herein are photographs and descriptions of the sort of clouds the lookouts identify and record, and instructions on the use of equipment for finding the position and velocity of clouds. Although written primarily for the northern Rocky Mountain area in summer, the cloud-observation techniques will be applicable elsewhere.

The Skyfire cloud survey is based on an integrated network of mountain-summit stations. Three times a day, when his fire lookout duties do not interfere, each lookout uses a simple coding system to record cumulus clouds and upper clouds on small cards which represent the area within 20 miles of his station. When the cards from all lookouts are assembled at headquarters on appropriate maps, the sky condition is automatically plotted for study. The plotting card technique greatly reduces the work of preparing the cloud maps for analysis. The lookouts also pay special attention to lightning conditions, and fill out forms and cards on each storm in their observation zone. Once a day the lookouts radio in a coded description of the day's weather, to give up-to-date information to forecasters and to project analysts.

Project Skyfire is primarily concerned with lightning, and hence thunderstorms. The development of cumulus clouds into thunderstorms is studied. Of special interest are the "breeding areas" where cumulus clouds most commonly get their start, or where their growth is most pronounced. Upper clouds and upper winds are studied because there can be a relationship between upper air conditions and thunderstorms and associated fire weather.



CLOUDS WITH VERTICAL DEVELOPMENT

STANDARD CUMULUS TYPES

- Cumulus

- Towering cumulus
- Towering cumulus with virga (precipitation not reaching the ground)
- Towering cumulus with precipitation

- Ice-top cumulus
- Ice-top cumulus with virga
- Ice-top cumulus with precipitation

- Thunderstorm

SPECIAL TYPES

Acc — Altocumulus castellatus

Figure 2. Clouds with vertical development.

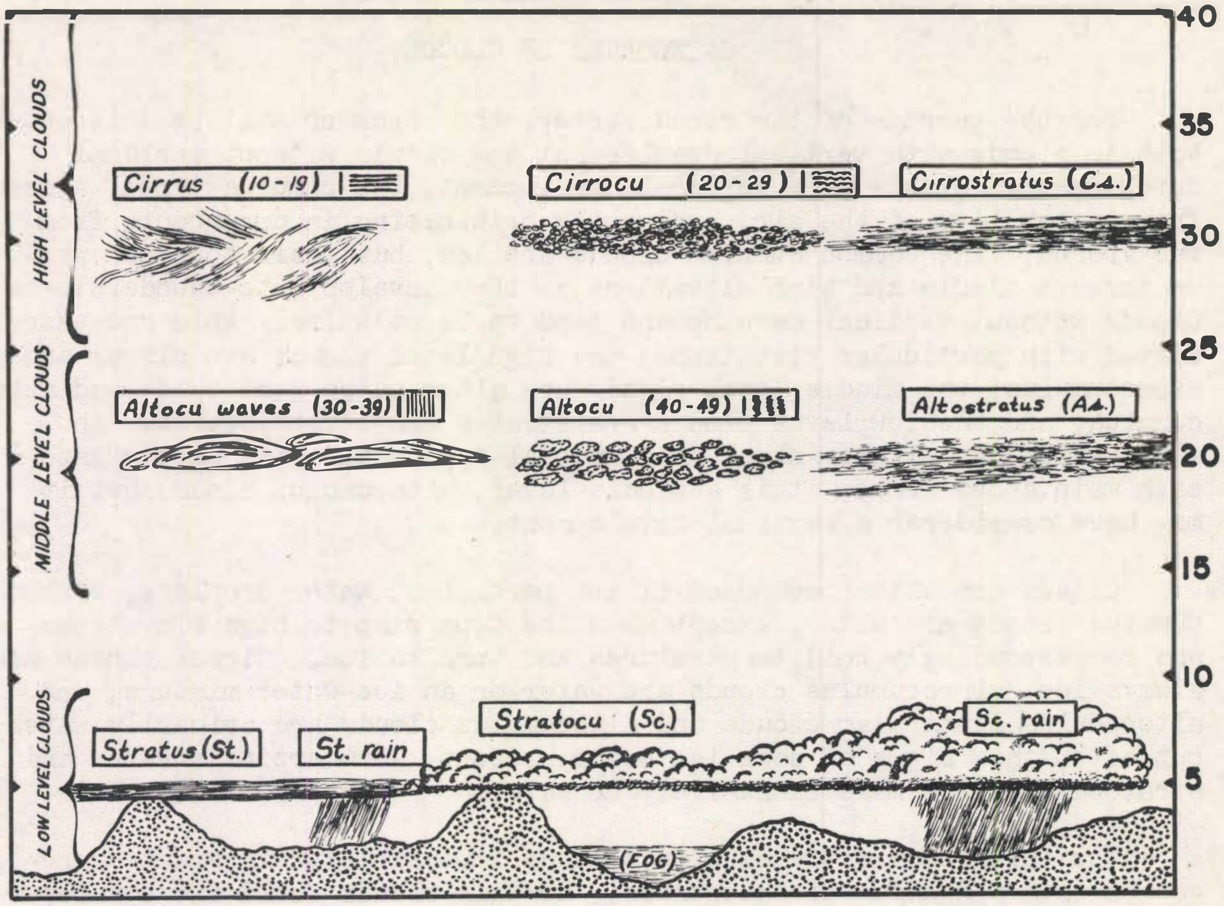


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Figure 3. Clouds without vertical development.

II. CLOUD IDENTIFICATION

CATEGORIES OF CLOUDS

For the purpose of the cloud survey, the observer will be interested both in clouds with vertical development and clouds without vertical development. Clouds with vertical development, the cumulus types, arise from instability of the air, ordinarily originating in upcurrents from the ground. The common cumulus clouds are low, but their tops can grow up through middle and high elevations as they develop into thunderstorms. Clouds without vertical development tend to be relatively thin and associated with particular elevations; the high level clouds are cirrus and cirrocumulus, the middle level clouds are altocumulus lenticular and altocumulus, and the low level clouds are stratus and stratocumulus. An altocumulus castellatus cloud is a special type which fits partly into each main cloud group; it is a middle level, altocumulus cloud, but it may have considerable vertical development.

Clouds are either composed of ice particles, water droplets, or both. Cumulus clouds are water, except when the tops rise to high elevations and correspondingly cold temperatures and turn to ice. Cirrus clouds are always ice, cirrocumulus clouds are water or an ice-water mixture, and altocumulus lenticular clouds and altocumulus clouds are primarily water, but often show signs of some ice being present. Summertime stratus and stratocumulus are made exclusively of water.

The infinite variety of clouds makes impossible their exact segregation into a handful of categories. Certain clouds could fit equally well into 2 or even 3 of the types given here. When this ambiguity exists, it is unimportant which classification is selected. The analysts realize the limitations of such cloud-observation data, so fire lookout observers need not worry when the cloud does not fit well into the most likely classification.

CUMULUS CLOUD TYPES

The family of cumulus clouds begins with the small fair weather cumulus and extends through the larger, more impressive stages up to the thunderstorm. In a typical summer situation small cumulus may develop around midmorning, grow to large proportions by early afternoon, and become thunderstorms by late afternoon. These thunderstorms are called airmass type. All the clouds in the cumulus family tend to have a characteristic cauliflower appearance on the top and rather flat bases. Even when the sky cover is so complete that the cloud tops cannot be seen, an observer can identify the cumulus type by the appearance of the bases. In an airmass situation the observer generally sees some clouds grow from small cumulus to thunderstorm proportions, even though the airmass thunderstorms which reach him can be blown in from another area. Many of the summer thunderstorms are of frontal types or due to instability aloft; they move in from another area while already developed, and the observer cannot witness the growth of the cumulus from the small edges.

Small cumulus clouds grow and decay in about 5 to 15 minutes. Large cumulus are composed of various smaller cells; while each cell may only be short lived, the whole cloud mass can exist much longer, as new cells feed it. Individual thunderstorms can last for hours.

Cumulus (⌓)

A cumulus cloud is the visible top of an upcurrent. Often birds can be seen to soar in the rising air under the cloud. A typical small, fair weather cumulus is merely the product of an upcurrent; the energy for the upcurrent comes from the heating of the air near the ground. A large towering cumulus or thunderstorm likewise marks an upcurrent, but the cloud itself is producing the major portion of the energy forming the cloud.

On many typical days there will be fog clouds in the valleys in the early morning. In midmorning regular cumulus clouds will be present. In the meantime the early fog will have disappeared, or the fog clouds will slowly rise to become the ordinary cumulus. The cumulus bases increase in

Figure 4. Cumulus clouds. Underneath each of these flat clouds is a strong upcurrent. Bases here are about 5,000 feet above ground, and the clouds are about 1,000 feet thick.

Figure 5. Cumulus clouds. These thicker clouds also show the flat bases that typify the type, and they illustrate the cauliflower appearance of the tops. Bases are at 5,000 feet, and the tops reach 8,500 feet.

height as the surface temperature rises, and their tops also go higher. The cloud thickness may increase or decrease as the day advances. Cumulus clouds form first and are biggest over mountains. The surface wind during the day often blows towards mountains and up the sides, becoming the air which feeds the upcurrents.

Towering Cumulus ( )

When ordinary cumulus clouds grow large, they are called towering cumulus. To differentiate them arbitrarily from the small cumulus, cumulus are said to be towering if they are over 7,000 feet thick or are thicker than the distance between the bases and the valley floor. This rule is to differentiate between small clouds which are powered principally by ground heating and the bigger clouds which are powered mostly by the release of latent heat of condensation in the cloud itself.

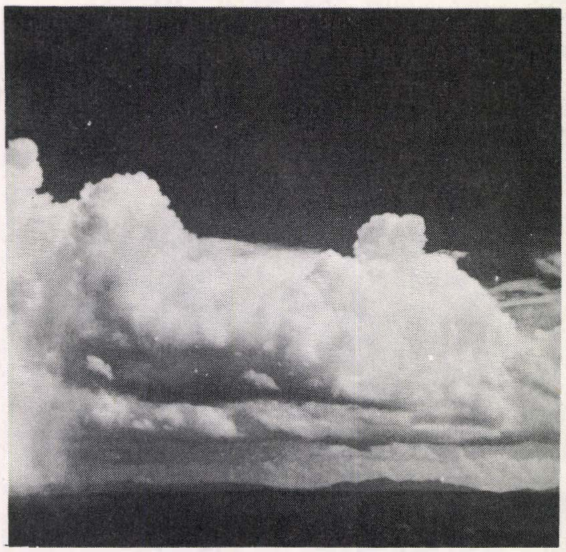

Figure 6. Towering cumulus. This towering cloud soon became a thunderstorm. At its present stage the base is approximately 7,000 feet above the ground and the top about 12,000 feet higher. Notice the characteristic flat base.

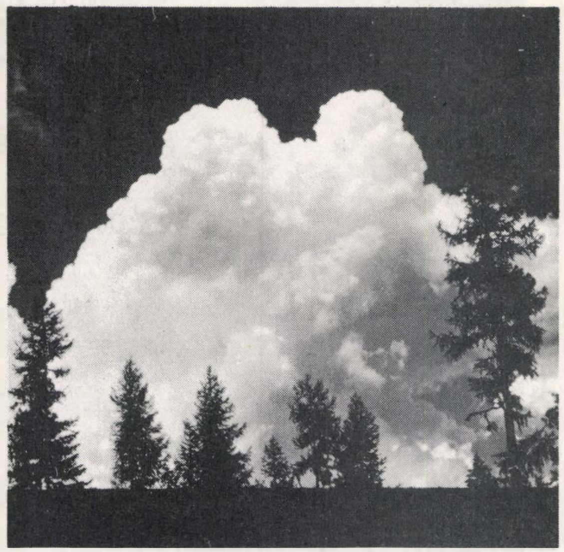

Figure 7. Towering cumulus. These cloud tops demonstrate the sharp-edged cauliflower appearance which characterizes large growing cumulus clouds. The temperature in the top portions of this cloud mass is below freezing, but the droplets which make up the cloud are still liquid water--they do not freeze because there is a lack of suitable freezing nuclei.

Towering cumulus are composed entirely of water droplets. Sometimes the clouds are so thick and have such strong upcurrents inside that they yield rain. The symbol for this cloud is the towering cumulus symbol with a "P" (precipitation) in it. If the precipitation does not reach the ground, a "V" (virga) is used.

Ice-Top Cumulus (V P)

The presence of ice in clouds can have a lot to do with the formation of precipitation and lightning, so it is useful to make note of the ice when it can be seen. Therefore a special category has been made for cumulus clouds showing ice. A "V" in the symbol means virga, and a "P" denotes precipitation. The edges of an ice cloud look more diffused and fuzzy, less sharp and less hard than the edges of a cloud composed entirely of water. In dry air ice particles do not evaporate as rapidly as water droplets, so at the cloud edges, where dry air mixes with the cloud air, ice particles

Figure 8. Ice-top cumulus. This cloud top is about 18,000 feet above sea level, and has a temperature of around -20° C. The top on the right is an ordinary towering cumulus and has the typical hard cauliflower appearance; the top on the left has definitely turned to ice (either it has gone higher and reached a colder temperature where the freezing nuclei can act, or it has been at cold temperatures so long that even inefficient freezing nuclei became effective).

can last a long time while water droplets disappear rapidly. This permits the ice edges to be diffuse, sometimes even fibrous. Sometimes, as in figure 8, it is easy to distinguish between water edges and ice edges. Often the difference is subtle, and different observers will have varying opinions.

In the northwest United States in summer the cloud tops will often be as cold as -20° C. without ice forming; sometimes there are insufficient nuclei to permit freezing even at this low temperature.

The ice tops often spread out flat, giving the cloud an ice crown. Often the cloud shape can be likened to a flat-topped toadstool or an anvil. On certain occasions water cloud tops will flatten in a similar manner, but the water crowns do not have the diffuse ice appearance.

<u>Large Cumulus with Unobservable Tops</u> ( )

A wiggly line near a symbol is often used to show that the symbol may be incorrect. When cumulus clouds become so dense that the tops cannot be observed, they must still be reported but the observer cannot tell what to report. In such cases the appropriate wiggly line symbol is used. Even when the tops cannot be seen, clouds can be identified as cumulus types by the shape and flatness of the bases. Usually the clouds could be seen forming before they cover the whole sky.

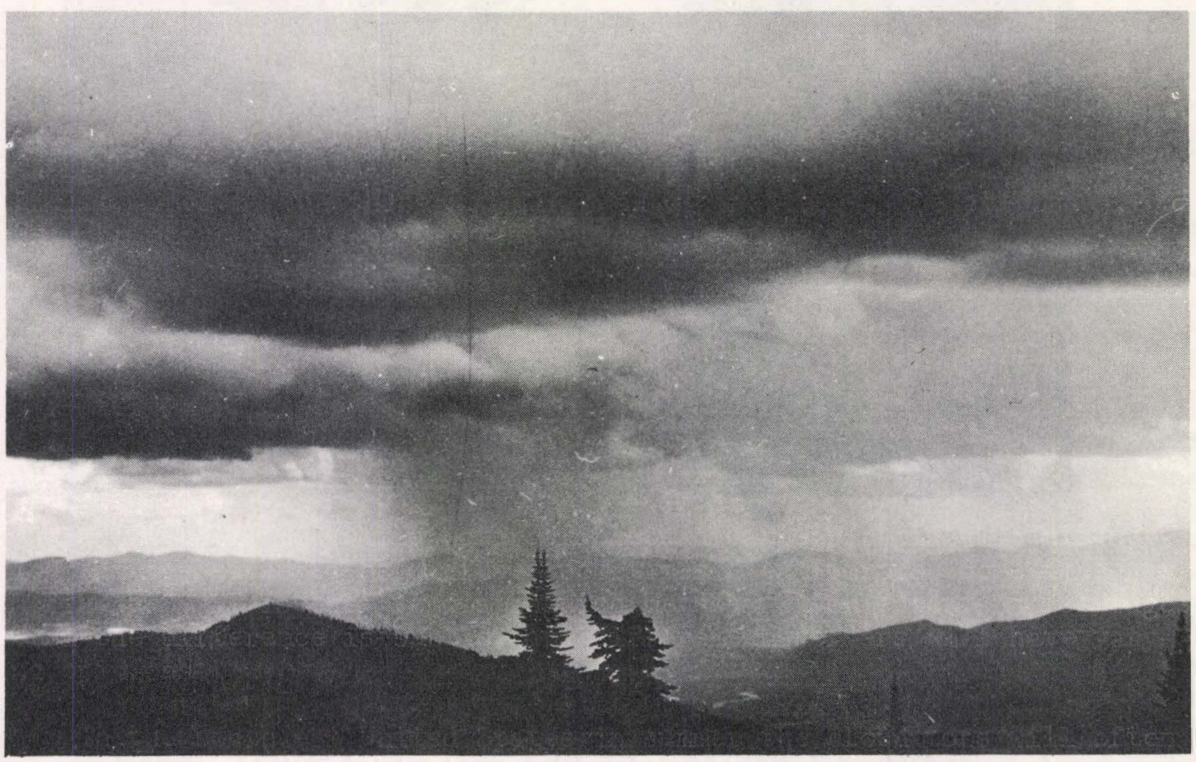

Figure 9. Rain from large cumulus, tops unobservable. Here precipitation is falling from the bases of large cumulus clouds, but the tops are not visible. The symbol to describe this situation is . The tops may have ice in them or they may not; both alternatives occur commonly in summer in the northwest United States.

Thunderstorm ( )

A thunderstorm is a storm with lightning. The sound of thunder arises as the air is heated by the passage of lightning, then the sound moves out at about 5 miles per second. Some of the lightning strokes are within the cloud mass or between clouds, and some are cloud to ground.

Lightning may come from a small storm only 20,000 feet high, but large thunderstorms often rise over 40,000 feet and occasionally reach 50,000 feet or more. The base of a thunderstorm may be 15,000 feet

Figure 10. Distant thunderstorms. All thunderstorms have ice at the top. The ones shown here tower to 40,000 feet and it can be seen that the whole outside upper portion is ice. Often high winds blow the anvil top off into a long streamer.

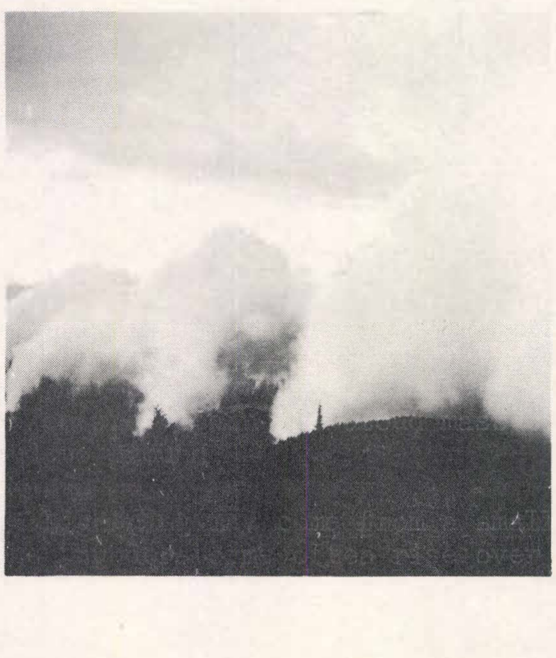

Figure 11. Thunderstorm advancing toward lookout. This menacing storm engulfed the lookout several minutes after the picture was taken. It contained 40 m. p. h. winds which could be heard in the trees as it approached. Severe lightning and heavy precipitation accompanied the storm.

above the ground, or it can come right down into the valley, covering the hills. Sometimes thunderstorms are accompanied by hail; usually they produce varying amounts of rain. On occasion the base is so high and the rain so light that no rain reaches the ground--this is termed a "dry storm."

Altocumulus Castellatus (Acc)

Altocumulus castellatus clouds look almost identical to some forms of regular cumulus, but differ from them in that they begin as middle level clouds. Altocumulus castellatus are formed by instability aloft, rather than by the upcurrents from the ground which cause cumulus. These clouds are excellent indicators of moisture and instability aloft, and are therefore of special interest to lightning fire research. They appear most commonly in the early morning, disappearing before the regular cumulus begin. On occasion they grow high enough to yield virga, rain, and even lightning. In such cases it is virtually impossible to distinguish them by appearance from ordinary towering cumulus and thunderstorm types, and they can be classified as such.

Figure 12. Altocumulus castellatus. The fog in the lower right corner shows the surface air is stable; these clouds must arise from instability aloft. The bases have a smooth, wavelike appearance.

Figure 13. Ordinary cumulus. These ordinary cumulus clouds are shown here for comparison. They mark upcurrents from the ground. Note that their bases are rougher than those of altocumulus castellatus.

Figure 14. Altocumulus castellatus in rows. This regular arrangement of turreted clouds in rows is common. The bases of these particular clouds are 17,000 feet above sea level.

HIGH AND MIDDLE LEVEL CLOUDS

Clouds at middle and high levels are important to identify because they give information on conditions aloft. They indicate the presence of moisture, they herald the coming of large storm systems, and they help show the position of streams of fast-moving air.

The clouds are divided into types consistent with those adopted by the U. S. Weather Bureau (when possible), but here the types are tailored to the special region involved and to the special information the clouds should give. For example, certain cloud types are good indicators of the jet stream. The jet stream is a band of high velocity air, typically 50 to 100 miles wide and several miles thick, at an average altitude of 7 miles. It may reach velocities of 200 knots, although in the summer in the northwest United States a speed of 90 knots is more likely. The jet stream causes strong vertical wind shear (different wind velocities at nearby altitudes) at the elevations of high and middle level clouds. The shear tends to draw long lived cirrus wisps out into extended lines, put ripples and wavelets on other clouds, and create wave clouds such as the altocumulus lenticulars. Thus, whenever middle and upper clouds are present, the jet stream makes its presence known by its effects on their structure. There are 2 categories of high clouds and 2 categories of middle clouds. Numbers have been assigned to clouds in each category. As a general rule, in any one category the higher the number the "faster" the cloud type. The high number clouds look "fast," and the chances are that they are formed in high winds.

The 2 high cloud categories are the cirrus types, composed of ice, and the cirrocumulus types, made of water or of a mixture of ice and water. The composition of the clouds is used to differentiate between the categories of high clouds. The 2 middle cloud categories are the altocumulus lenticular type, which marks the tops of huge, smooth atmospheric standing waves, and the altocumulus types, which move with the wind. The motion of the clouds is used to differentiate between the categories of middle clouds. Middle clouds are principally composed of water. Sometimes ice streamers (virga) can be seen in them; this is worth while to note becuase it gives information on the presence of freezing nuclei at these altitudes.

The few high and middle cloud identification rules to be given here cannot suffice for all cases. For example, one difficulty the observer will experience is differentiating between various altocumulus and cirrocumulus clouds. Sometimes the 2 are very different, sometimes almost indistiguishable, and sometimes 2 edges of 1 cloud will show characteristics of both levels. Therefore there is not always just 1 correct answer in cloud identification; an error may be due to incorrect categories rather than incorrect observing.

Cirrus Types

All the cirrus types are composed of ice and have a characteristic decayed fibrous structure. They are thin clouds. They occur at various elevations, but a reasonable average height is 30,000 feet above sea level. Because ice crystals evaporate slowly, cirrus clouds are long lived and the winds can distort them into weird shapes.

Wispy Cirrus (12)

Wispy cirrus consists of wisps and torn masses, oriented at random.

Figure 15. Wispy cirrus (thin). This common form looks like icy fibers that have diffused irregularly

Figure 16. Wispy cirrus (thick). This picture is an extreme example, with the clouds so thick they show puffiness. The random, washed out, fibrous look typifies wispy cirrus.

Ribbed Cirrus (14)

Cirrus is called "ribbed" when it forms a long, regular pattern of lines going sideways from a main line. It can be likened to a fish skeleton, with the ribs going out from the backbone in a pattern.

Figure 17. Ribbed cirrus. "Ribs" streaming off main "backbone" show characteristic cirrus ice texture.

Figure 18. Ribbed cirrus. Commonly the "backbone" of such a cloud parallels wind direction.

Streamers of Cirrus (15)

Often trails of ice drawn out by differing winds at lower altitudes stream from tiny cells of high clouds. Sometimes the tiny "generating clouds" evaporate leaving just the streamers.

Figure 19. Small streamers of cirrus. These little hooks originated in high velocity cloud puffs. As the streamers descended, they were drawn back by the slower air.

Figure 20. Large streamers of cirrus. "Generating clouds" are clearly visible. Streamers indicate moderate, vertical wind shear.

Bands of Cirrus (18)

Many different cirrus shapes fit into the "Bands of Cirrus" type. They all are very drawn out in the direction of the wind, and therefore look "fast." Commonly the bands extend from horizon to horizon. There may be many parallel ones or a single one. They are among the best indicators of high velocity air motion.

Figure 21. Bands of cirrus. These drawn-out cirrus shapes show the effects of strong wind shear.

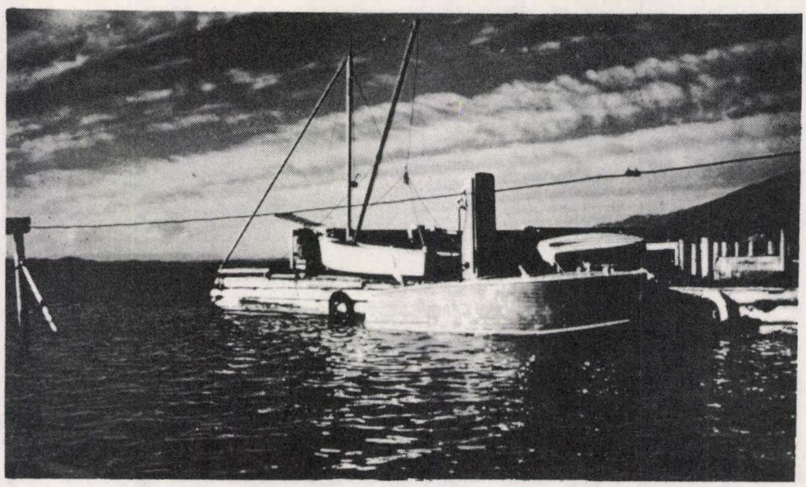

Figure 22. Segmented bands of cirrus. These very definite bands of cirrus are broken into segments. A closer view might even show them to be ribbed, but their predominant characteristic is their over-all band appearance.

Cirrocumulus Types

Cirrocumulus clouds originate as water clouds and then evaporate quickly or decay to ice and become one of the cirrus types. All have a structure of tiny cells, ripples, or waves on them. Such cells, ripples, or waves can also be observed on middle level clouds, but they appear more delicate in the cirrocumulus types. Cirrocumulus clouds change in shape and detail rapidly. Often a patch of cirrocumulus will be a standing wave cloud, and the ripple structure will blow through the motionless cloud patch. If the patch evaporates steadily at the downwind edge, it means the cloud is water; ice would not evaporate quickly and would thus leave a streamer downwind. High, thin, water clouds often show iridescence, a sort of irregular shape of rainbow colors. An average height for cirrocumulus is 28,000 feet above sea level, but the clouds are sometimes so low they cannot be separated from the middle cloud types.

Cloudlets of Cirrocu (24)

Cloudlets of cirrocu are made of water. The cloud consists of a fairly solid mass of tiny, more or less irregular puffs.

Figure 23. Cloudlets of cirrocu. Such cloudlets look thin and waterish. If ice does form in them, it washes them out to a thin cirrus.

Patterned Cirrocu (25)

The patterned cirrocu shows small, firm waves, ripples, or cells, and is one of the most spectacular and beautiful cloud forms. The waves may be parallel, perpendicular, or at some other angle to the cloud movement. The detailed structure changes rapidly.

Figure 24. Patterned cirrocu. These little waves give a regular pattern. Some parts of the cloud mass have started turning to ice; they resist any pattern changes and so give an out-of-focus appearance.

Figure 25. Patterned cirrocu. Thick sheets of patterned cirrocu have a definite wrinkled appearance. Cirrocu cloudlets are forming in the distance.

Figure 26. Rollers in patterned cirrocu. These rollers are indicative of a very strong wind. Their axes are perpendicular to the cloud movement.

Decaying Cirrocu (26)

If sufficient freezing nuclei are present, cloudlets of cirrocu and patterned cirrocu will slowly turn to ice and decay. They are called decaying cirrocu when they have so lost their detailed structure that it is no longer their predominant characteristic. When they have turned completely to ice, they are to be classified as one of the cirrus types. As long as a pattern is discernible, they are cirrocumulus types.

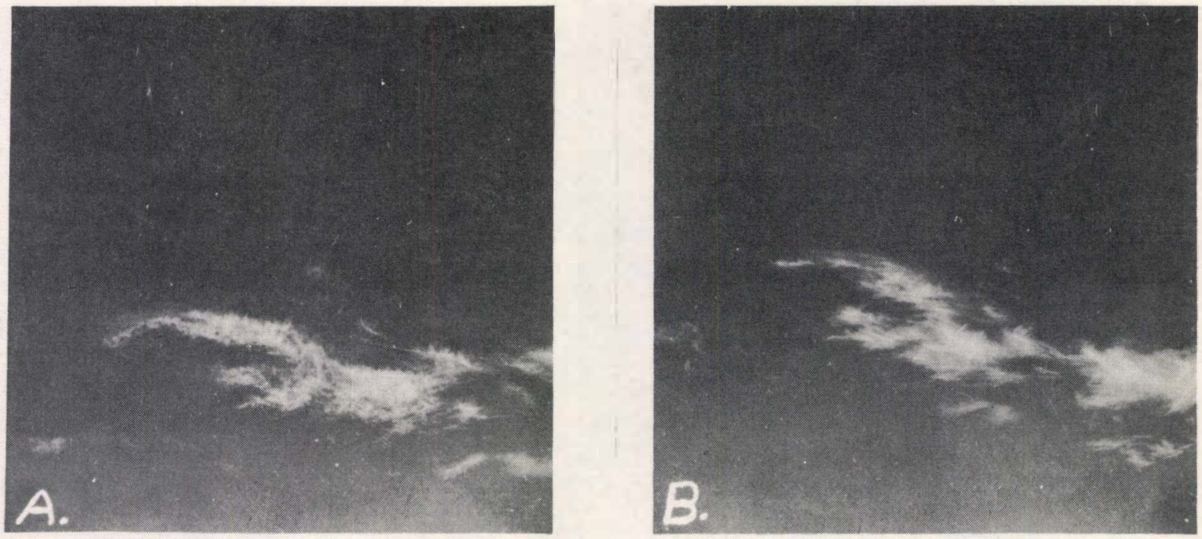

Figure 27. Decaying cirrocu. A, a patterned cirrocu cloud with a cell structure has started decaying to ice; B, same cloud 3 minutes later. It is now so completely ice that it would be classified as a cirrus type. Probably in a few more minutes it would be a good example of wispy cirrus.

Figure 28. Decaying cirrocu. Part of this cloud still retains enough pattern in it to cause it to be described as a cirrocumulus type. Some have decayed so far that they could be considered a cirrus type.

Altocumulus Lenticular Types

Lenticular clouds have lens-shaped cross sections. The base is very nearly flat, and the top is a smooth curve from the sharp edge upwind to the sharp edge downwind. These clouds mark the tops of wavelike upcurrents. Such upcurrents are most often found just downwind of mountains during strong wind conditions. The cloud and the wave are stationary, and the wind rushes through them. The cloud motion therefore cannot show the wind velocity, but the more firm and sharp edged the cloud, the stronger the wind. Behind large mountains the upcurrents and downcurrents can be felt as high as 50,000 feet; so, of course, high level as well as middle level clouds will be affected by them. If the lenticular clouds are below 25,000 feet above sea level, they can be considered of the altocumulus (middle level) variety. In the northwest United States in summer, higher wave-produced clouds will generally have a structure putting them in the patterned cirrocu type.

Lenticular Altocu (36)

This is the only type of middle level standing-wave-produced cloud, but it exists in a wide variety of forms. Often cloud upon cloud is piled up like a stack of saucers, and at other times the cloud will just be a thin sinuous line paralleling a mountain chain. The clouds are almost invariably water; droplets are in them such a short time that freezing is unlikely. Sometimes freezing occurs and a long ice plume will extend far downwind outlining the wavy ups and downs of the air motion.

Figure 29. Lenticular altocu. This double decked cloud is just downwind of the mountain range (the wind is from the viewer). It indicates a strong wind aloft.

Lenticular Altocu (36) (Continued)

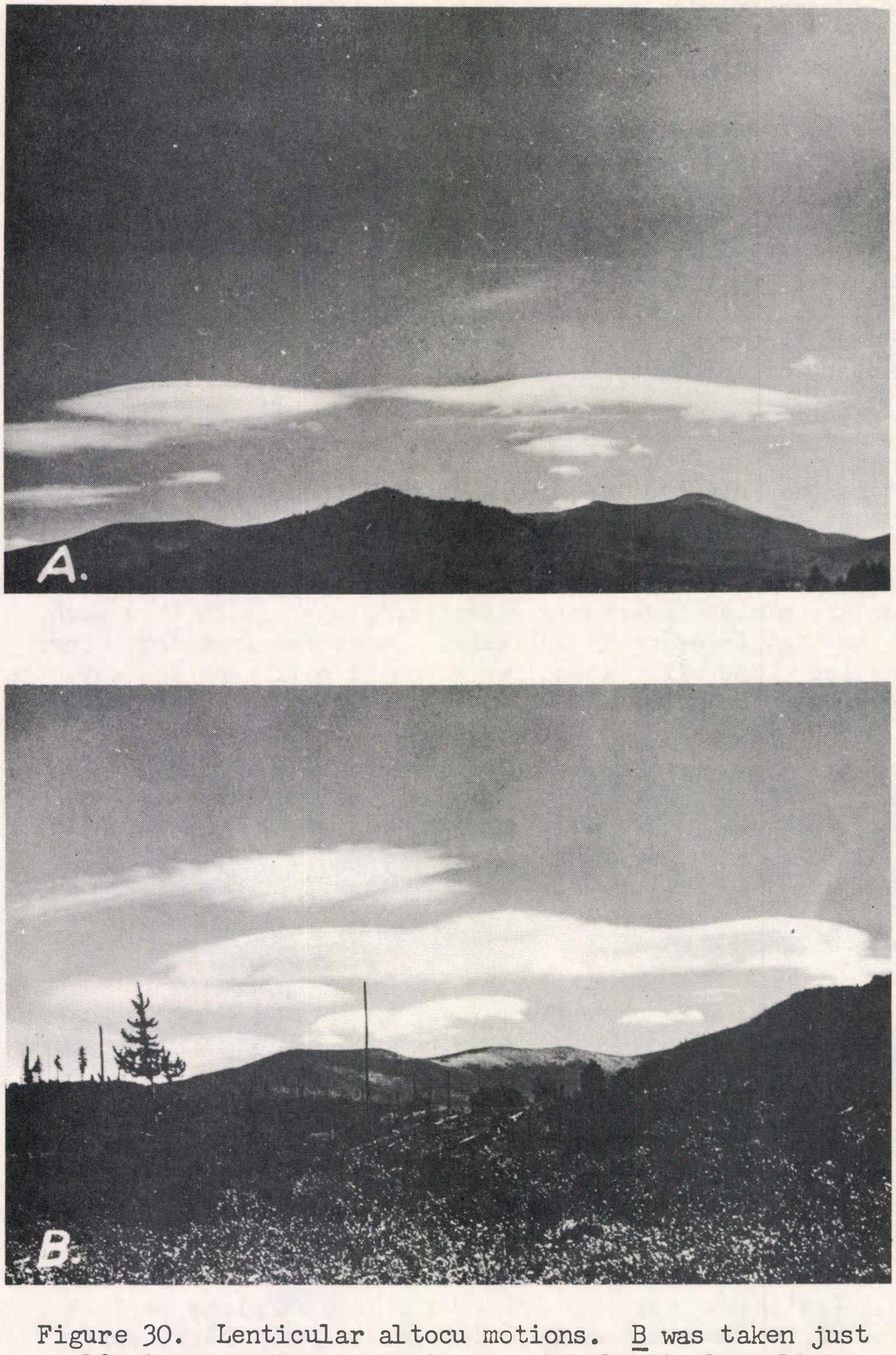

Figure 30. Lenticular altocu motions. B was taken just 13 minutes after A showing how the lenticular altocu has grown. Such rapid changes of shape and size are common. Note the cloud mass is still in the same position just downwind of the mountains.

Altocumulus Types

Middle level clouds which move with the wind are the altocumulus types. They may be as low as 15,000 feet above sea level, or as high as 25,000 feet. They are thin, and usually rough textured. They are usually composed of liquid water droplets although colder than freezing. Often some ice does form in them, and the ice filaments (virga) hang down from the parent altocumulus. Altocumulus types may be present anytime but are seen most often in the early morning.

Patches of Altocu (41)

Shapeless areas of altocumulus are called patches of altocu. Their predominant characteristic is that they have no definite form.

Figure 31. Patches of altocu. This middle layer cloud mass is about 1,000 feet thick, and here situated 19,000 feet above sea level. Around the edges it shows a tendency to break up into cloudlets.

Chaotic Altocu (42)

Many times the sky will be full of altocumulus patches, cloudlets, and moving lenticular clouds, usually topped by some cirrus forms. The catchall type for this situation is chaotic altocu.

Figure 32. Chaotic altocu. This picture shows various types of middle level clouds.

Cloudlets of Altocu (43)

The most typical middle level cloud form consists of a mass of distinct, irregular cloudlets. When thin, they are called cloudlets of altocu. If very thick and towering, they are altocumulus castellatus.

Figure 33. Cloudlets of altocu, with and without ice virga. These cloudlets are 20,000 feet above sea level. They are beginning to show some smooth areas where ice virga is coming from them.

Patterned Altocu (44)

Patterned altocu are altocumulus cloudlets arranged into a definite pattern, such as in rows parallel to the wind, rows perpendicular to the wind, or a combination of the two. As a general rule, the more spectacular the arrangement, the faster the middle level wind.

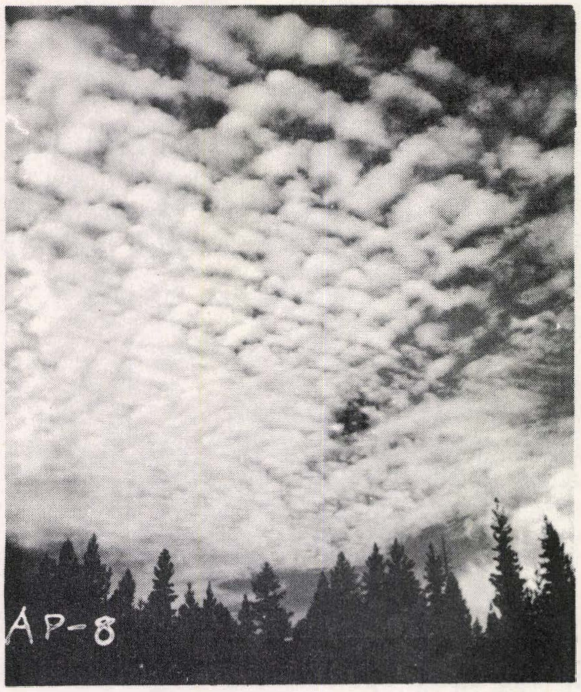

Figure 34. Patterned altocu. The pattern in this case is a symmetrical one, with as many definite lines parallel to the wind as perpendicular to the wind.

Figure 35. Patterned altocu lines. Here the cloudlets are arranged in rows perpendicular to the wind and cloud motion.

Figure 36. Patterned altocu in long lines. This impressive cloud form was associated with a wind of 70 knots.

Corrugated Altocu (46)

When a middle level cloud demonstrates a smooth waviness rather than appearing to be a collection of rough cloudlets, it is termed corrugated altocu. Just like water waves, these waves are perpendicular to the wind.

Figure 37. Corrugated altocu. Just as water waves are produced when wind blows over water, cloud waves can be formed when a strong upper wind blows over a weaker lower one. In this picture the smoothness of the waves is apparent.

Continuous Patterned Altocu (48)

The commonest form of patterned altocu is that having rows perpendicular to the wind. If there are many consecutive rows downwind of each other (say 10 or 20 or more) the pattern is described as continuous patterned altocu. The main difference between this and corrugated altocu is simply that the corrugated type is smooth and the continuous patterned altocu is still composed of rough-edged cloudlets. In the most spectacular examples, continuous patterned altocu rows stretch from horizon to horizon.

Figure 38. Continuous patterned altocu. The wind and clouds are blowing away from the observer, forming a long line of cloudlet rows.

Figure 39. Continuous patterned altocu arranged downwind. Cloudlets in lines parallel to the cloud motion.

Blank

CIRRUS

#12
Wispy cirrus
(page 13)

#14
Ribbed cirrus
(page 13)

#15
Streamers of
cirrus
(page 14)

#18
Bands of
cirrus
(page 15)

CIRROCUMULUS

#24
Cloudlets of
cirrocu
(page 16)

#25
Patterned
cirrocu
(page 17)

#26
Decaying cirrocu
(page 18)

Review of high cloud pictures (Ci and Cc).

Figure 40.

ALTOCUMULUS

#41
Patches of altocu
(page 21)

#42
Chaotic altocu
(page 22)

#43
Cloudlets of
altocu
(page 22)

#44
Patterned
altocu
(page 23)

#46
Corrugated
altocu
(page 24)

#48
Continuous
patterned
altocu
(page 24)

ALTOCUMULUS LENTICULAR

#36
Lenticular altocu
(pages 19 & 20)

Review middle cloud pictures (Acl and Ac).

Figure 41.

MISCELLANEOUS CLOUD TYPES AND NOTES

The cloud observer will see clouds which cannot be fitted into the cumulus types, high cloud types, and middle cloud types that he has been asked to observe. For the sake of completeness some of these clouds will be described here.

Stratus.--(A low level cloud.) This is a solid, smooth cloud deck at very low elevation--a dreary overcast. Light rain may fall from it.

Stratocumulus.--(A low level cloud.) These low clouds can resemble ordinary cumulus, but they are not formed by upcurrents from the ground. They are like altocumulus clouds down at low elevation. Sometimes rain falls from a thick overcast of stratocu.

Altostratus.--This is the very smooth, flat, featureless member of the middle cloud group.

Cirrostratus.--This is a smooth, thin, featureless high cloud type. Except when it is unusually thick the sun can be detected through it. If there is a halo ring circling the sun and 22 degrees away from it the cirrostratus is made of ice.

False cirrus.--Under some conditions the body of a thunderstorm cloud will dissipate, leaving its ice crown high in the air. This crown or anvil top can last a long time and blow far away from where it originated. By appearance alone it cannot readily be distinguished from a dense example of wispy cirrus. The best way to identify false cirrus is to see if formed. (See figure 2.)

Contrails.--Under certain altitude and temperature conditions the water released by aircraft engines during fuel combustion makes a condensation trail. Conditions are most often suitable at high altitudes, such as cirrus cloud level and above. Sometimes the trails disappear immediately; sometimes they break up into pendants, loops, and other odd shapes (the shape depending in part on the kind of plane producing them); and occasionally they persist and are similar in appearance to ribbed cirrus or other cirrus types.

Figure 42. Contrails. These condensation trails were left by a jet bomber. Since cirrus clouds were present nearby the situation for contrail formation was very favorable, and the trails lasted a long time.

Figure 43. Wide angle cloud photograph. This typical summer scene in Montana shows cumulus clouds of various sizes with bases 6,000 feet above the valley, topped by wispy cirrus at 27,000 feet.

Figure 44. Patterned cirrocu and lenticular altocu. Here is a standing wave patterned cirrocu area, composed of water and having a structure of cloudlets, waves, and cells blowing through it, above a standing wave lenticular altocu. The picture shows how one cloud type can be merged with another, making typing difficult.

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III. CLOUD MEASUREMENT TECHNIQUES

Simple measurements from the ground can often give the position, height, temperature, velocity, and composition of a cloud. There are a variety of methods available, depending on the type of cloud and equipment on hand. To describe the methods briefly:

CLOUD POSITION

1. Find the position by triangulation from 2 stations where the azimuth angles are known.

2. If the height is known or can be estimated, the distance to the cloud can be found by some device giving elevation angles, such as a modified astro-compass, an Abney level, an Osborne firefinder, a theodolite, or a nephoscope. Refer to MF form G, page 32.

3. If the cloud shadow can be seen, the cloud can be located closely on a map.

4. The cloud's structure sometimes locates it roughly with respect to topographic features (for example, cumulus clouds over ridges rather than valleys, and lenticular altocu just downwind of mountains).

5. If the cloud is producing lightning, its distance can be estimated by noting the time between the flash and the resulting thunder. The thunder occurs approximately 5 seconds after the flash for every mile distance. The lightning can also be detected by the static on an AM radio receiver.

CLOUD HEIGHT

1. If the cloud distance is known by one of the methods just listed (1, 3, 4, or 5 above), then the cloud height or thickness can be found by some device giving elevation angles, such as a modified astro-compass, etc. Refer to MF form G, page 32.

2. If the cloud is of a cumulus type caused by the heating of surface air, the height of its base can be estimated if the surface dry bulb and wet bulb temperatures are measured. MF form A, page 33, shows cumulus cloud base height versus these temperatures.

If the base height is known, an elevation measuring device will show the distance to the cloud and then the height of the cloud top can be calculated.

3. Knowledge of the type of cloud often helps in guessing its altitude, especially for the case of high level clouds without vertical development. For example, in the northern Rocky Mountains in summer, cirrus and cirrocumulus clouds average about 30,000 feet above sea level. This figure will generally be close enough so high

USING ELEVATION ANGLE TO FIND HEIGHT OR DISTANCE

IF CLOUD DISTANCE IS KNOWN, ELEVATION ANGLE GIVES CLOUD HEIGHT ABOVE OBSERVER.
IF CLOUD HEIGHT ABOVE OBSERVER IS KNOWN, ELEVATION ANGLE GIVES CLOUD DISTANCE.

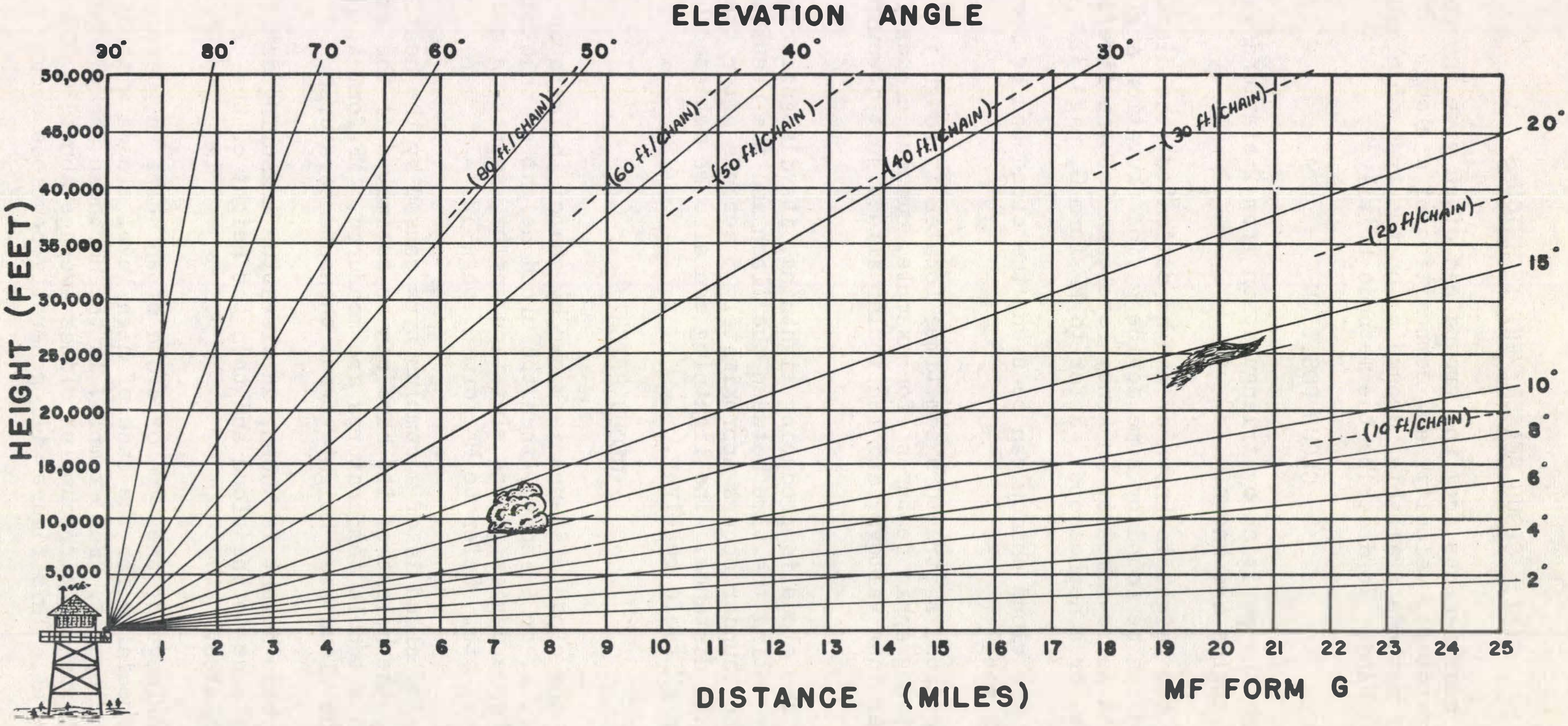


Figure 45. MF Form G. This graph represents a side view of the lookout and the clouds being observed. For the cumulus cloud shown, if the base is known to be 8,000 feet above the observer, the center of the base (being at 13° elevation angle) must be 7½ miles away. Since the top is also 7½ miles away, it (being at 20° elevation angle) must be 13,000 feet above the observer. For the cirrus cloud shown, which is here assumed to be 24,000 feet above the observer, the elevation angle of 13½° corresponds to a distance of 20 miles.

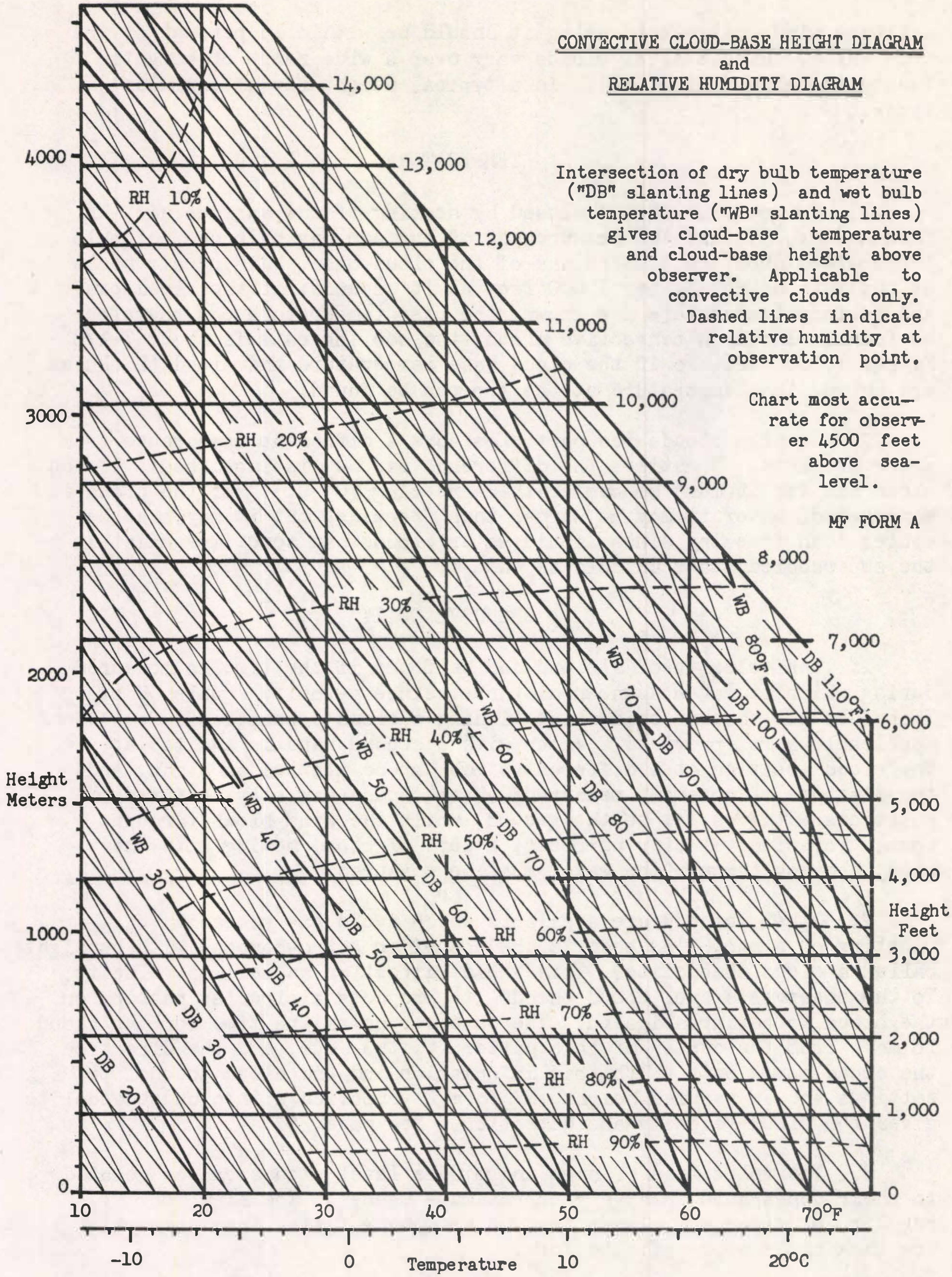


Figure 46. MF Form A.

altitude winds calculated using it should be within 15 percent of the true value. Middle level clouds vary over a wide range of heights. Twenty thousand feet m. s. l. is a typical height for altocumulus types.

TEMPERATURE

1. For cumulus clouds caused by heating of the surface air, MF form A (page 33) and the measurement of surface dry bulb and wet bulb temperature show the temperature of the cloud base. Rising air cools at the rate of $5\frac{1}{2}^{\circ}$ F. per 1,000 feet as it ascends; if the cloud base and surface temperature are known, the base temperature can therefore be found. Inside a convective cloud, the cooling rate is about 3-1/3° F. per 1,000 feet, so if the cloud base temperature and cloud thickness are known, the temperature at the top can be found.

2. In high clouds ice particles have a different appearance from water droplets. Sometimes the difference can be distinguished. If the cloud has ice it must be cooler than freezing (0° C.). If the cloud is composed of water it may be warmer than freezing, but it may also be cooler than freezing since liquid water clouds can sometimes exist in the supercooled state as cold as -40° C.

CLOUD VELOCITY

1. The velocity of a cloud can be found if the time is measured during which it moves a known distance, since velocity equals $\left(\frac{\text{distance}}{\text{time}}\right)$. Therefore all that is said about finding a cloud's position is applicable here, provided a watch with a second hand is available. The cloud location at 2 different times can be plotted on a map, and the distance of movement measured. Wave clouds may stay in fixed positions with respect to the ground, while the wind blows through them. For wind velocity purposes, a puff of cloud moving with the wind, blowing through the wave, must be measured.

2. Other methods are available which avoid the necessity of plotting on a map. The best is the use of an astro-compass with gunsight, called a cloud theodolite. This yields direction as well as velocity. To the observer's eye, cloud theodolite projects a circular pattern on the cloud to be investigated. The observer notes the time for the cloud to move from the center of this pattern to the edge, and the direction the cloud moves out. With this information and the cloud theodolite settings and an assumed height, MF form F (supplied with cloud theodolite) gives the cloud velocity and direction. See page 35.

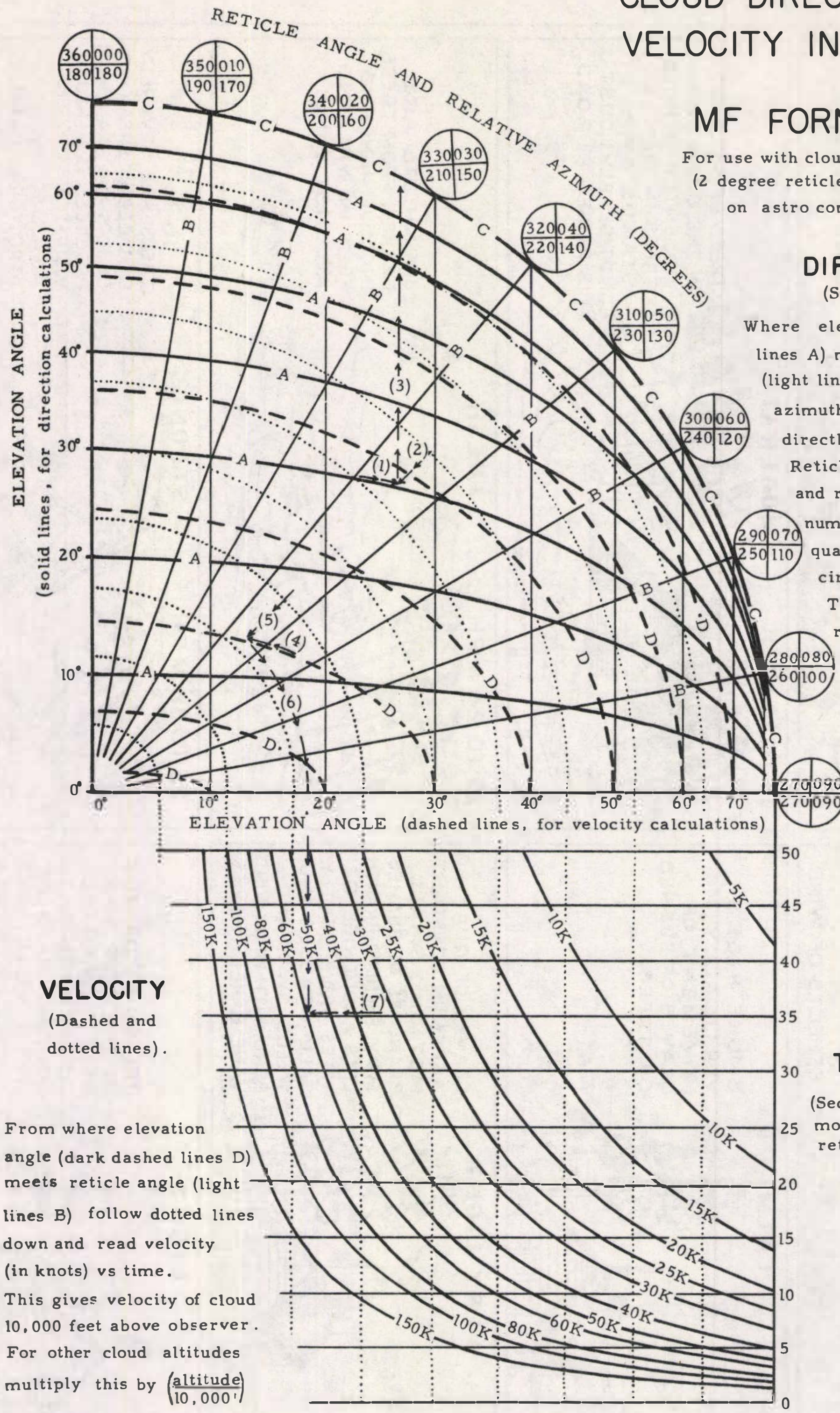
3. The velocities of high and middle level clouds can be related to their appearance in a <u>very</u> approximate manner. The firm, or regular, or drawn out clouds tend to be moving faster than ones which are lacking in such definite form.

4. The strength of the surface wind can be estimated with the aid of the "Northern Rocky Mountain Scale of Wind Velocity," which relates

CLOUD DIRECTION AND VELOCITY INDICATOR

MF FORM "F"

For use with cloud theodolite (2 degree reticle gun sight on astro compass).



DIRECTION

(Solid lines).

Where elevation angle (dark lines A) meets reticle angle (light lines B) read relative azimuth of motion on C directly above.

Reticle angle numbers and relative azimuth numbers are in same quadrant of number circles.

This method gives relative direction toward which the cloud moves.

VELOCITY

(Dashed and dotted lines).

From where elevation angle (dark dashed lines D) meets reticle angle (light lines B) follow dotted lines down and read velocity (in knots) vs time.

This gives velocity of cloud 10,000 feet above observer. For other cloud altitudes multiply this by $\left(\frac{\text{altitude}}{10{,}000'}\right)$ to get actual velocity.

TIME

(Seconds for cloud to move from center to reticle circle edge)

EXAMPLE Given: Elevation 30°, Reticle angle 225°, Time 35 seconds, Cloud altitude 15,000 feet.

Direction: Follow solid elevation angle (1) to where it intersects reticle angle (2). Find relative azimuth angle directly overhead (3). Answer: 206 degrees.

Velocity: Follow dashed elevation angle (4) to where it intersects reticle angle (5). From there follow dotted lines (6) to horizontal time line (7). Read velocity for 10,000 foot cloud (60K). Correct for altitude. Answer: 90K.

Figure 47. MF Form F. Form used with cloud theodolite to determine cloud direction and velocity.

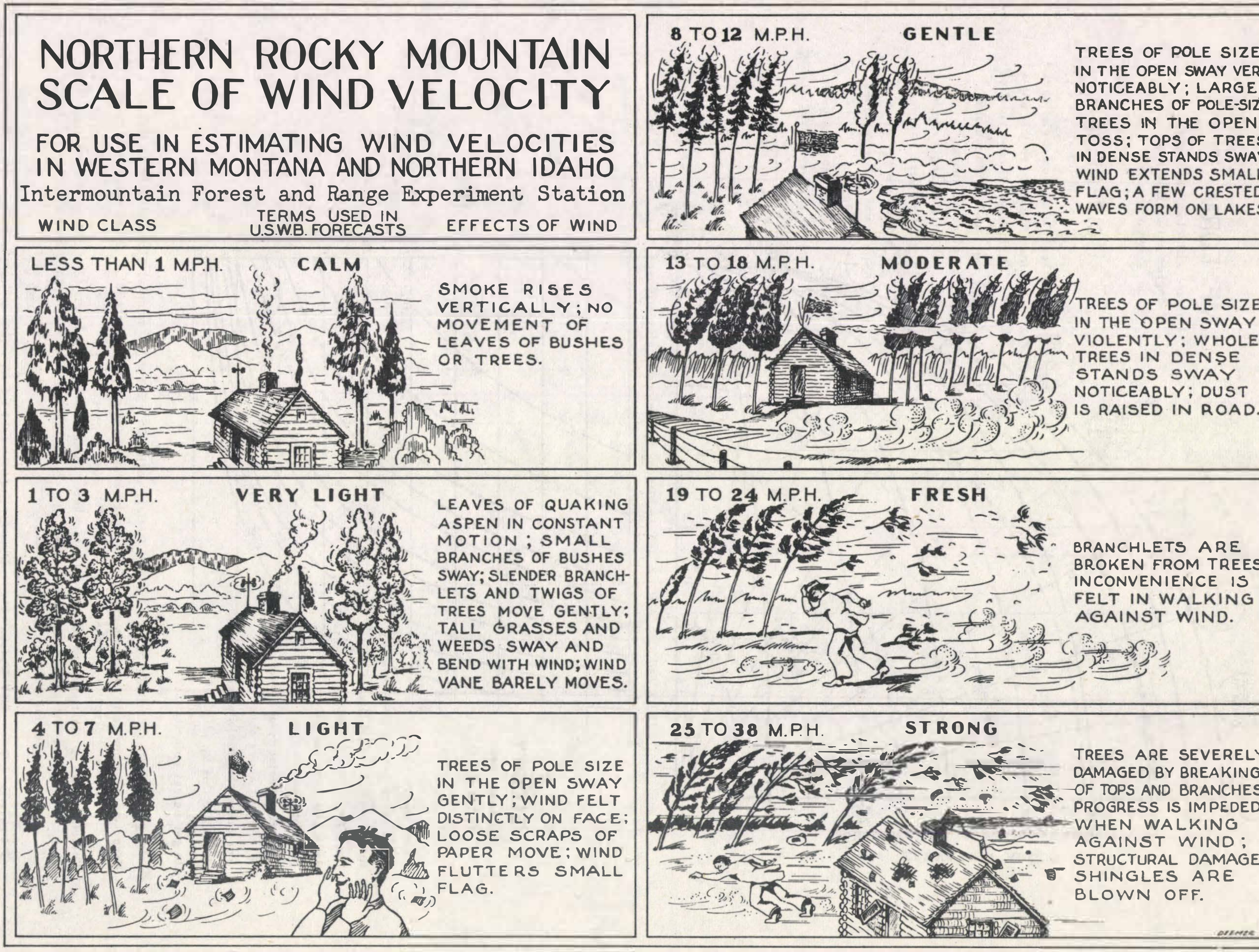

NORTHERN ROCKY MOUNTAIN SCALE OF WIND VELOCITY
FOR USE IN ESTIMATING WIND VELOCITIES IN WESTERN MONTANA AND NORTHERN IDAHO
Intermountain Forest and Range Experiment Station
WIND CLASS
TERMS USED IN U.S.W.B. FORECASTS
EFFECTS OF WIND
LESS THAN 1 M.P.H.
CALM
SMOKE RISES VERTICALLY; NO MOVEMENT OF LEAVES OF BUSHES OR TREES.
1 TO 3 M.P.H.
VERY LIGHT
LEAVES OF QUAKING ASPEN IN CONSTANT MOTION; SMALL BRANCHES OF BUSHES SWAY; SLENDER BRANCHLETS AND TWIGS OF TREES MOVE GENTLY; TALL GRASSES AND WEEDS SWAY AND BEND WITH WIND; WIND VANE BARELY MOVES.
4 TO 7 M.P.H.
LIGHT
TREES OF POLE SIZE IN THE OPEN SWAY GENTLY; WIND FELT DISTINCTLY ON FACE; LOOSE SCRAPS OF PAPER MOVE; WIND FLUTTERS SMALL FLAG.
8 TO 12 M.P.H.
GENTLE
TREES OF POLE SIZE IN THE OPEN SWAY VERY NOTICEABLY; LARGE BRANCHES OF POLE-SIZE TREES IN THE OPEN TOSS; TOPS OF TREES IN DENSE STANDS SWAY; WIND EXTENDS SMALL FLAG; A FEW CRESTED WAVES FORM ON LAKES.
13 TO 18 M.P.H.
MODERATE
TREES OF POLE SIZE IN THE OPEN SWAY VIOLENTLY; WHOLE TREES IN DENSE STANDS SWAY NOTICEABLY; DUST IS RAISED IN ROAD.
19 TO 24 M.P.H.
FRESH
BRANCHLETS ARE BROKEN FROM TREES; INCONVENIENCE IS FELT IN WALKING AGAINST WIND.
25 TO 38 M.P.H.
STRONG
TREES ARE SEVERELY DAMAGED BY BREAKING OF TOPS AND BRANCHES; PROGRESS IS IMPEDED WHEN WALKING AGAINST WIND; STRUCTURAL DAMAGE. SHINGLES ARE BLOWN OFF.

Figure 48.

the wind strength to commonly noted effects. This scale was developed for wooded valley areas; fire lookouts atop hills will find the wind to be stronger than it indicates. See page 36.

CLOUD COMPOSITION

It is useful to be able to tell whether a cloud is composed of ice particles, water droplets, or both. Ice crystals and water droplets have differing optical characteristics which help to distinguish them. Also the evaporation rates of ice and water are materially different, which provides another approach whereby the observer can decide between ice and water.

Optical Effects

Ordinary rainbows and the rainbow-colored iridescence common in altocumulus clouds indicate the presence of water droplets. Colored coronas a few degrees around the sun also are evidence of water (in irregular clouds these are the iridescence). The "glory," a ring surrounding the shadow of an observer on clouds or fog below him is a spectacular indicator of liquid particles. On the other hand, halos around the sun or moon are indicators of ice clouds; they are not colored. The commonest halo phenomena are rings at 22° or 46° around the light source.

When the sun or moon is viewed through a cloud, the disc edge remains sharp if the cloud is liquid, but tends to blur and diffuse if the cloud is composed of ice crystals.

Evaporation

Under similar conditions, ice particles evaporate more slowly than water droplets. At the edge of a cloud near the top, dry outside air causes evaporation of the cloud: quickly, leaving a sharp edge, if the cloud is liquid; slowly, leaving a softer, less sharply defined edge, if the cloud is formed of ice particles. Towering cumulus tops and ice tops illustrate the extremes in convective clouds. If a cloud edge fragment does not evaporate within 5 minutes, it is probably ice.

Altocumulus clouds, composed primarily of water, often show "fallstreifen" or virga snow descending from them. Such clouds start as water, and in later stages are composed of ice and water, with the puffy water cloud on top and the fibrous ice trails below. The virga, incidentally, looks just like the virga which is rain falling from ordinary warm cumulus clouds, but trails descending from altocumulus clouds must be snow because the clouds are too thin to develop raindrops.

Cirrocumulus clouds originate as droplets, and are continually altering shape. Sometimes parts of the cloud then become ice, the texture gets diffused, and the static, fibrous ice structure begins resembling the true ice cirrus.

HOW TO USE THE CLOUD THEODOLITE

The cloud theodolite is a handy meteorological tool for finding cloud positions and velocities. It is adapted from 2 war surplus items: an aircraft gunsight (in which the observer sees a lighted reticle design superimposed on distant objects), mounted on an astro-compass (a device for setting at an exact elevation angle and azimuth angle). A new light source has been installed in the gunsight so it can be operated by portable batteries, and the shape of the reticle has been altered so that cloud directions and velocities can readily be found. An inexpensive stopwatch is clipped on to the gunsight; it is needed for velocity measurements.

On the face of the stopwatch there is a sticker saying "TURN OFF LIGHT." To save the batteries you must always remember to turn off the light. It should be off before you look at the stopwatch, but the sticker is put there as a reminder. Some of the cloud theodolites have a dim light and a bright one. To save the batteries, use the dim light whenever feasible.

Setting Up The Cloud Theodolite

The cloud theodolite base should be put permanently at a convenient height at a corner of the lookout station. It should be so oriented that the cloud theodolite points north when the azimuth scale reads zero. If this is impossible, a correction will have to be added to each azimuth measurement. After the cloud theodolite is set on the base, it should be leveled (bubbles centered) by means of the 2 flat wheels near the bottom of the unit. In case the gunsight has not been set exactly on the astro-compass, it is wise to compare the elevation reading from the cloud theodolite with the known elevation angle to some distant points; if the cloud theodolite is incorrect, it can be adjusted with a screwdriver.

Finding Cloud Azimuth and Elevation Angles

1. Set cloud theodolite on the base and level it.

2. Switch on light (using "Dim" instead of "Bright" if possible.)

3. Set center point of illuminated reticle on the cloud. Use the left hand to turn the elevation angle knob, and the right hand to change the azimuth angle of the whole unit.

4. TURN OFF LIGHT.

5. Read the azimuth and elevation angles on the appropriate scales.

Finding Cloud Motion, Direction, and Velocity

1. Set cloud theodolite on the base and level it.

2. Make sure stopwatch is wound and has its sweep second hand stopped on zero.

3. Switch on light.

4. Set center point of illuminated reticle where the cloud will blow through it.

5. Start the watch as the cloud passes the center point and stop it when the cloud reaches the reticle edge.

6. TURN OFF LIGHT.

7. Record on MF form 7 the azimuth angle (column 4), elevation angle (column 5), direction the cloud moved across reticle and time interval (column 7). Estimate the cloud height, and use form F to find the cloud direction and velocity.

NOTE: The direction found from form F is the direction toward which the cloud moves and the wind blows. Wind directions are ordinarily reported as the direction from which the wind blows, so on form 7 there is a column for each of these directions.

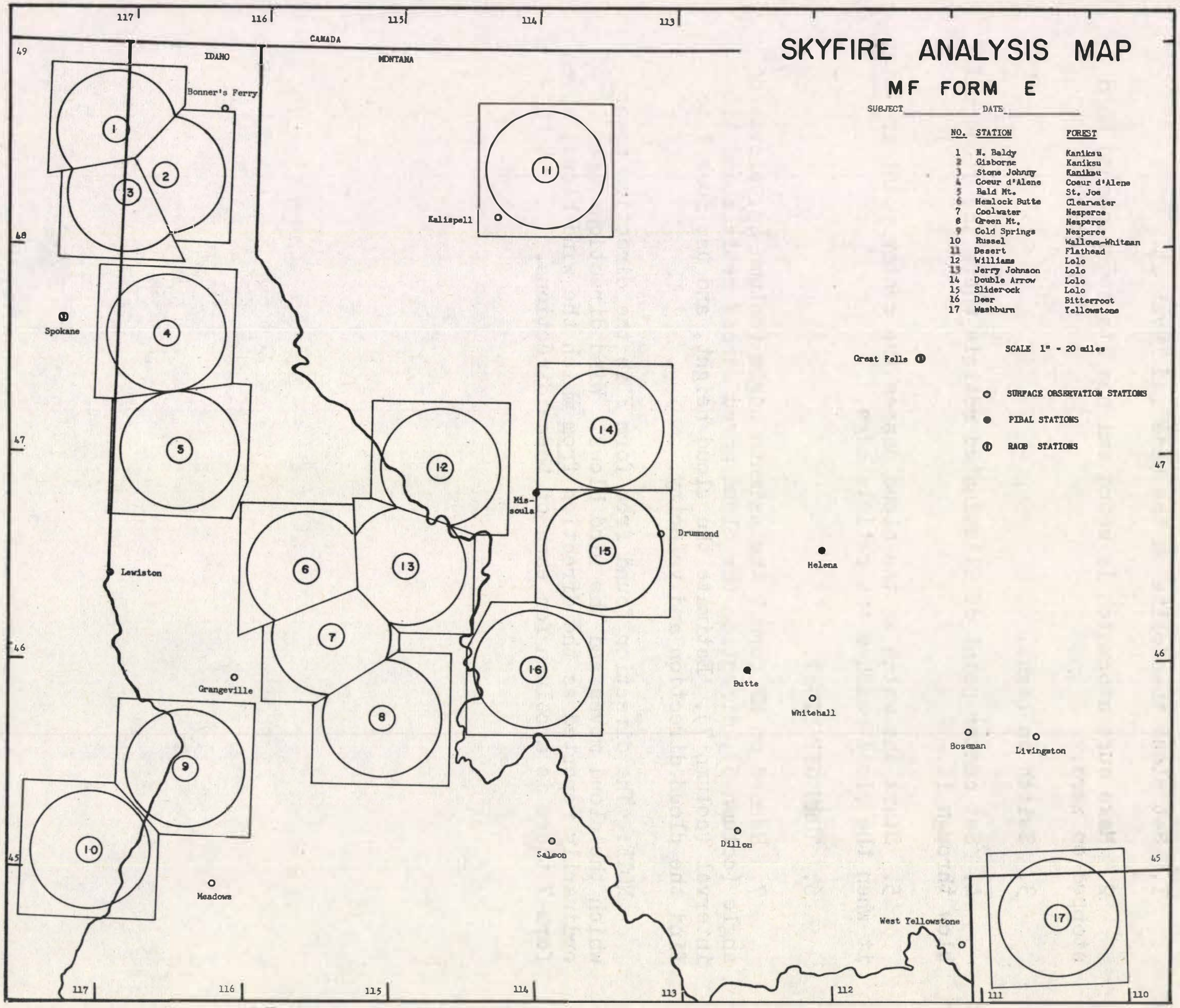


Figure 49. MF Form E.

IV. CLOUD AND LIGHTNING SURVEY

Project Skyfire employs a network of forest fire lookout stations (figure 49) to survey general cloud and lightning situations over a broad territory of the northern Rockies. This chapter describes the specific methods used in the survey and outlines duties of the observers manning the stations.

CLOUD SURVEY

The lookout firemen at Project Skyfire stations observe and record cloud data 3 times each day. These data are entered on form 7. A sample instruction sheet for form 7 is on page 42 and a form 7 (slightly reduced scale) is shown on page 43.

When making a cloud observation the observers identify the type and location of upper clouds. This information is entered on the proper plotting card at the top of form 7. Next the observer identifies the type and location of cumulus clouds and enters this information on the proper plotting card of form 7. All clouds plotted on the cards must be within a radius of 20 miles of the lookout station.

The plotting cards of form 7 have been specifically designed to aid in the forming of regional cloud maps. When form 7 is received at Project Skyfire headquarters the plotting cards are cut off and affixed to appropriate maps which are thus automatically plotted. Figure 49 is a picture of the map on which the completed cards are glued. Note that observation areas overlap in some areas making it necessary to clip the corners from some cards. The cards are printed with red ink; the plotting of information is done with dark ink to provide contrast.

The observation techniques used on upper clouds enable Skyfire observers to also record upper winds data on form 7. At the morning, noon, and afternoon observation times an upper cloud which can be readily followed in the cloud theodolite is selected to obtain data on wind speeds and direction.

In addition to the observations of upper and cumulus clouds at specific times special items related to clouds and winds are recorded on form 7. Special items recorded include maximum cumulus activity at other than regular report times, rate of growth of cumulus clouds, severe surface winds, hail, rain, and spectacular high level clouds.

The data and maps assembled from form 7 provide the basis for studying cloud action and winds in relation to other atmospheric factors. These data show where cumulus clouds first form. They indicate the cloud-breeding areas where cumulus clouds most often form and grow. They provide part of the background for piecing together the life cycle of lightning storms. They also provide general information on fire weather and the day-to-day variations in fire danger.

INSTRUCTIONS FOR FORM 7

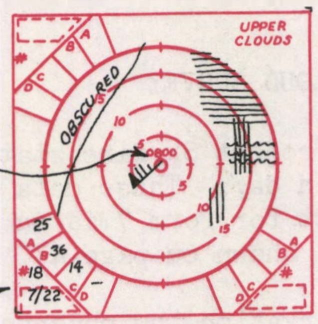
(1) Each day fill out the appropriate "Upper Cloud" cards, "Cumulus and Surface Conditions" cards, and "Upper Winds Data" at 0800, 1200, and 1600 m. s. t.

(2) Make sure station number and date are on each card and on page center.

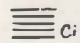
(3) Make sure the line is drawn which shows the area coinciding with that of another lookout. For data use a corner inside this line.

UPPER CLOUD CARD

Cloud Motion: (Optional)
Draw arrow coming <u>from</u> direction wind comes from.
▲ =50K | =10K | =5K
Sample shows wind from SW at 75 K.
Unless cloud type used is under "A" in corner, write type number over arrow.



Draw in cloud areas (<u>not</u> individual clouds) using this <u>code:</u>

 Ci
12 Wispy Cirrus
14 Ribbed Cirrus
15 Streamers of Cirrus
18 Bands of Cirrus

 Cc
24 Cloudlets of Cirrocu
25 Patterned Cirrocu
26 Decaying Cirrocu

 Acl
36 Lenticular Altocu (circle around number denotes ice virga)

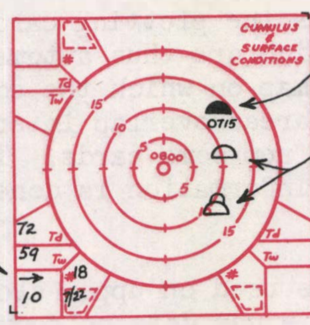
 Ac
41 Patches of Altocu
42 Chaotic Altocu
43 Cloudlets of Altocu
44 Patterned Altocu
46 Corrugated Altocu
48 Continuous Patterned Altocu (circle around number denotes ice virga)

Fill out corner assigned to your station. Date and station number as shown. Put number of most prominent cloud type in A, next most prominent in B, etc. Use only 1 type each of Ci, Cc, Acl, and Ac unless the 4 spaces permit more. "—" denotes no clouds.

If sky is clear of upper clouds, write "NONE" near middle of card. If obscured, write "OBSCURED." If altocumulus castellatus (Acc), cirrostratus (Cs), or altostratus (As) is present, write the appropriate symbol.

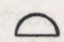
CUMULUS AND SURFACE CONDITIONS CARD

Fill out corner assigned to your station. Date and station number as shown. Surface wind in square: velocity (m. p. h.) and direction (arrow coming from direction wind comes from). Sample wind, 10 m. p. h. from W.
Td = Dry Bulb Temperature
Tw = Wet Bulb Temperature



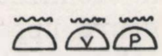
On the 0800 card <u>only</u>, show position of first cumulus by . Under the symbol put the time of appearance.

Show areas of cumulus activity with appropriate symbol:

 Cumulus

 Towering Cumulus (with virga, with precipitation)

 Ice-top Cumulus (with virga, with precipitation)

 Large Cumulus with unobservable tops (with virga, with precipitation)

 Thunderstorm

If sky is clear of cumulus types, write "NONE" near middle of card. If obscured, write "OBSCURED." If there is a general rain, write "RAIN." If there is stratus (St) or Stratocumulus (Sc), write the appropriate symbol.

UPPER WINDS DATA

At the 3 observation times select an upper cloud which can be readily followed in the cloud theodolite, and fill out columns 2 to 7. OPTIONAL: Using form F, fill out columns 8 to 12, and plot motion on upper cloud card.

SPECIAL ITEMS

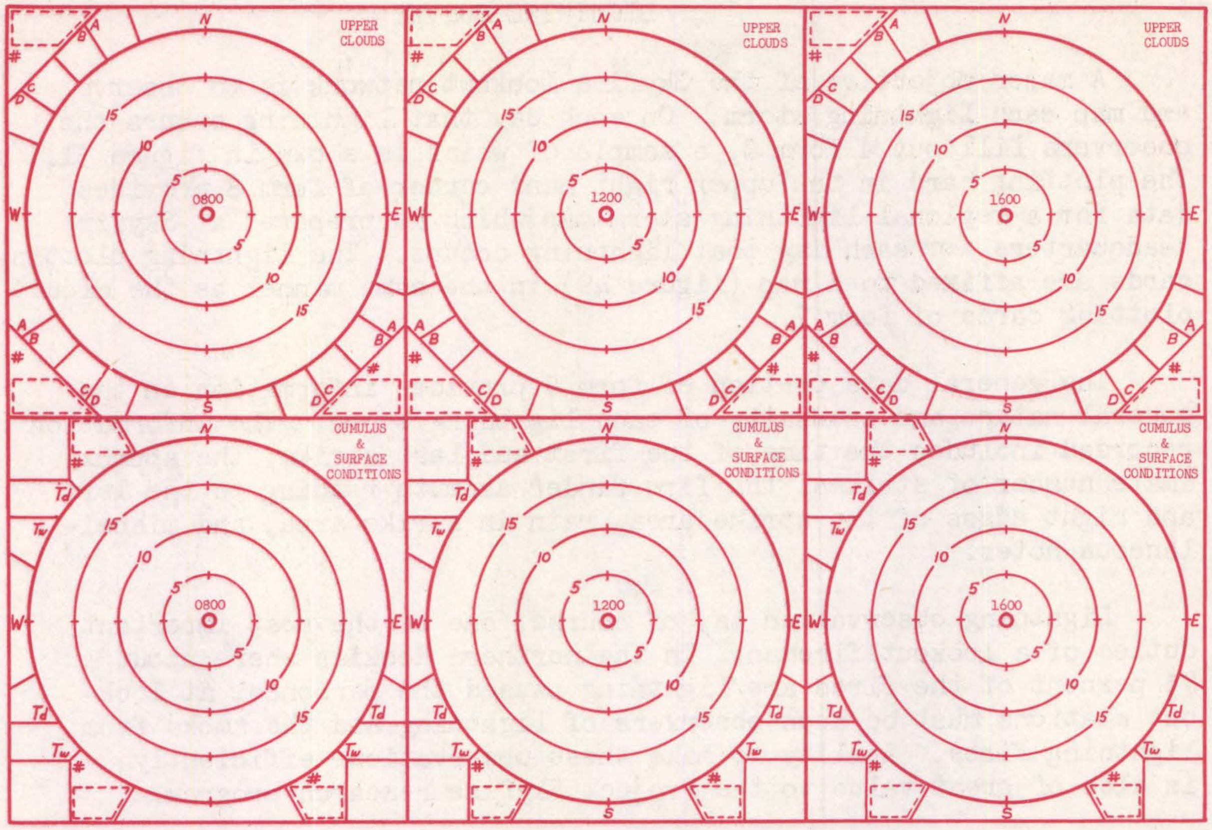
(1) <u>Explain information on cards above.</u> Describe any upper cloud, cumulus, or surface conditions which are difficult to record on the cards. Give details of any cloud types which do not fit the cloud categories.

(2) <u>Record special events whenever they occur.</u> Describe spectacular high clouds or cumulus which are present between regular recording times. Note severe surface winds (greater than 25 m. p. h.), and hail. Give the approximate time of the start and end of rain. Mention unusual cloud conditions, persistent contrails, and false cirrus.

(3) <u>Check if lightning has occurred in past 24 hours. Report lightning in detail on form 8.</u> At the 1600 hour report lightning if it has occurred during the past 24 hours. Form 8 is provided for reporting lightning in detail.

NOTE: On the 1st and 15th of the month, put down general information concerning "cloud-breeding areas" near you.

Figure 50. Form 7 instructions.



FORM 7
RF-INT
PREVENTION
Lightning Fire Research
Project Skyfire

DATE: Day 16 Month July 1955

STATION NAME Stone Peak Number 19

OBSERVER Bill Jones

UPPER WINDS DATA

1 HOUR	2 CLOUD TYPE USED	3 EST. ALT. ABOVE OBSERVER	4 CLOUD THEOD. AZIMUTH	5 CLOUD THEOD. ELEV.	6 DIR. ON RET-ICLE	7 SEC-ONDS	8 10,000' VELOCITY (FORM F)	9 ACTUAL VELOCITY	10 RELATIVE DIRECTION (FORM F)	11 DIR. CLOUD MOVES TO	12 DIR. CLOUD MOVES FROM	13 NOTES
0800	25	25,000'	85°	48.5°	330°	14	40 K	100 K	337°	062°	242°	—
1200	46	14,000'	060°	20.0°	290°	47	80 K	112 K	317°	017°	197°	—
1600	42	14,000'	005°	38.9°	015°	21	62 K	87 K	009°	014°	194°	—

SPECIAL ITEMS
(1) Explain information on cards above
(2) Record special events whenever they occur
(3) ☐ Check if lightning has occurred in past 24 hours. Report lightning in detail on form 8.

TIME	
0800	Upper cloud card: Cirrocu types showed iridescence. The ripples were perpendicular to the cloud types.
1200	Cumulus and Surface Conditions Card: Small amounts of virga falling from well developed towering Cu.

Form 7.

LIGHTNING SURVEY

A major objective of the Skyfire lookout network is to observe and map each lightning storm. On each day that lightning occurs the observers fill out a form 8, a sample of which is shown in figure 51. The plotting card in the upper right hand corner of form 8 provides data for a regional lightning storm map which is prepared at Skyfire headquarters for each day that lightning occurs. The lightning plotting cards are affixed to a map (figure 49) in the same manner as the cloud plotting cards of form 7.

The general data portion of form 8 provides information on the general nature and intensity of each lightning storm. The information recorded includes the time of the first and last strike, the approximate number of strikes, the fire finder azimuth reading to the left and right edges of the strike area, rain in strike area, and miscellaneous notes.

Lightning observation is, of course, one of the most important duties of a lookout fireman. In the northern Rockies where about 75 percent of the fires are lightning caused the personnel at lookout stations must be keen observers of lightning and the smoke from lightning fires. Ability to make these observations efficiently is also of great value to the Project Skyfire research program.

During a lightning storm the lookout fireman is very busy observing and recording strikes, taking fire finder readings on strike zones, looking for smokes, and in many instances reporting fires. Therefore, preparedness for lightning storm action is essential. Upon the approach of a storm a double check should be made to insure that everything is ready for action. Preparedness for lightning storm observation includes the following:

1. Lightning protection system for lookout and communication system in proper condition. Switches thrown if necessary.

2. Fire finder properly oriented.

3. Paper lightning strike ring ready for use on fire finder.

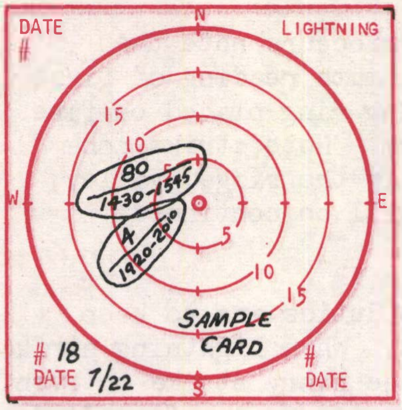
4. Map light ready for night use.

5. Food preparation or other housekeeping duties arranged so that there will be no interference with lightning observation and fire detection.

6. Fire report forms handy.

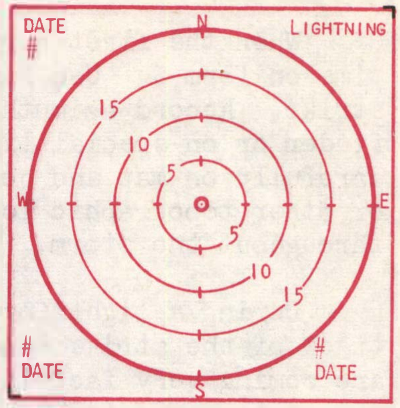
7. Project Skyfire form 8 ready for use.

8. Notify ranger station that storm is approaching.



LIGHTNING

Fill out this page (right hand card plus the information below) for each 0000 to 2400 m. s. t. period during which lightning strikes the ground.



Put the station number and the date on the card, in the corner assigned to the lookout, and on the form below. On the card, use fractions such as $\frac{80}{1430\text{-}1545}$ to designate the approximate number of strikes to ground (80) and the time of starting (1430) and stopping (1545). Arrow shows direction of storm movement. As in the sample card above left, enclose the numbers with a line to show the approximate area of the strikes. It is impossible to count the exact number of strikes, but in every case put down some number which is your best estimate. When the large size or long duration of a storm makes it complicated to plot, just do the best you can and put explanatory notes on the card.

FORM 8—LIGHTNING
RF-INT
PREVENTION
Lightning Fire Research
Project Skyfire

DATE: Day 22 Month July 1955

STATION NAME Stone Peak Number 18

OBSERVER Bill Jones

TIME START	TIME END	NO. OF STRIKES	AZIMUTH TO LEFT EDGE	AZIMUTH TO RIGHT EDGE (Circle If Within 10 Miles)	RAIN IN STRIKE AREA 2=Heavy 1=Light 0=None	MISCELLANEOUS NOTES: Optional. Note height of cloud tops, bases, or both. Note if many cloud-to-cloud strikes but few ground strikes, etc. Note any fires started, including time first observed.
1430	1545	80	285°	340°	1	-mostly cloud-to-
						cloud strikes.
1920	2010	4	257°	310°	0	-all cloud-to-ground
						strikes. One fire
						discovered (265°)
						at 2005.
TOTAL		84				

Figure 51. Form 8.

When the first strike from a lightning storm occurs note the time on form 8. Use fire finder to determine azimuth reading of first strike. Record azimuth reading on paper lightning ring placed on fire finder or on special lightning strike record form. Note strike zone carefully on map and be sure that you can identify the ridge, valley, or other topographic location. This procedure will be continued throughout the storm.

During a lightning storm the most important duties are to keep track of the strike zones and to watch for smoke. When lightning strikes are coming very fast it is rather difficult to see every strike or even to count every strike. A paper lightning strike ring on the fire finder aids greatly in keeping track of the strikes. Make a pencil mark at the proper azimuth on this paper ring for every strike that is seen. Even if there is not time to swing the fire finder alidade around to get an exact reading, place a pencil mark at the approximate azimuth of the strike. Keep doing this throughout the storm. When the storm is over the number of pencil marks will help in estimating the total number of strikes. The pencil marks will also show the general areas to be watched carefully for smokes.

Observation of rain on the strike areas is an important part of the lightning survey. Information is desired which will indicate whether the storm was dry with virtually no rain, moderately wet with a light shower, or was accompanied by heavy rain persisting for some time. If the rain gage at the lookout is hit by a representative amount of rain from the storm, some actual measurement will be available to judge general rainfall.

<u>On form 8:</u>

No rain to .04 inch of rain should be reported as none (0)

.05 to .20 inch should be reported as light (1)

More than .20 inch should be reported as heavy (2)

Note the approximate time that the last strike occurs. As soon as the storm is over, plot the general strike area on the form 8 plotting card. If there is more than one general strike zone show separate storm areas on the plotting card. Use an arrow on the plotting card to indicate direction of storm movement.

After the storm, continue to keep a sharp watch for smokes. Carefully search out the zones indicated by the pencil marks on the lightning strike ring on the fire finder. Watch for hangover smokes for many days after the storm. Remember that the rain areas are not safe. Many hangover fires may occur in an area hit by a lightning storm rain.

RADIO AND TELEPHONE REPORTS

Brief daily radio or telephone reports are received from all Project Skyfire lookout stations. These reports present fresh information daily on the general cloud and lightning situation within the observation zone of each station. Such reports enable the Skyfire staff to maintain constant information and to make live or "hot" analysis of lightning storms and the general regional cloud system. The daily reports also furnish valuable information to the fire weather forecasters of the U. S. Weather Bureau.

Specific instructions on radio and telephone reporting procedures will be furnished all Skyfire stations, forest dispatchers, ranger stations, and regional radio operators prior to each fire season. The reports are based upon the morning, noon, and afternoon observations of cumulus and upper clouds.

SUMMARY OF DUTIES--SKYFIRE LOOKOUT FIREMEN

Fire duties.--The first duty of Project Skyfire lookout firemen is to locate fires and to handle other fire-control assignments. All Project Skyfire duties are second to fire-control duties.

Skyfire duties:

Daily at definite times--Form 7

0800 Fill out upper cloud card, cumulus and surface conditions card, and upper winds data.

1200 Fill out upper cloud card, cumulus and surface conditions card, and upper winds data.

1600 Fill out upper cloud card, cumulus and surface conditions card, and upper winds data. Transmit Skyfire radio report.

Daily as required---Form 7

Fill out first cumulus part of 0800 card when first cumulus appears.

Fill out special items column. Note unusual weather phenomena as they occur.

Days with lightning--Form 8

Fill out lightning plotting card.

Fill out all appropriate columns on form.

Weekly or as soon as mail pickup permits

Send in completed forms 7 and 8 to: Forest Fire Laboratory, U. S. Forest Service, Missoula, Montana.

1st and 15th of month--Form 7

Record description of cloud-breeding areas in your area where cumulus clouds most often form and grow.